

Claims

- 1 1. A method of for measuring brain activity comprising:
 - 2 noninvasively obtaining signals of central nervous system (CNS) activity;
 - 3 localizing signals to specific anatomical and functional CNS regions which
 - 4 participate in reward/aversion functions;
 - 5 correlating the signals in a reward/aversion brain region; and
 - 6 interpreting the correlation results.
- 1 2. The method of Claim 1, wherein the reward/aversion regions are subcortical gray, brainstem, cerebellum and frontal brain regions.
- 1 3. The method of Claim 2 wherein the brainstem region includes the spinal cord.
- 1 4. The method of Claim 3 wherein the spinal cord includes the trigeminal nucleus and the method further includes the step of non-invasively obtaining signals from the trigeminal nucleus.
- 1 5. The method of Claim 3, wherein the reward/aversion regions include at least one of the GOb, VT/PAG, NAc, SLEA, cingulate gyrus, S1, S2, thalamus, insula, cerebellum, prefrontal cortex, amygdala, hypothalamus , parahippocampal gyrus, hippocampus, entorhinal cortex, ventral pallidum, dorsal striatum, M1, M2, SMA, FEF, RVM, and brainstem subnuclei.
- 1 6. The method of Claim 1, wherein obtaining signals of CNS activity includes using a neuroimaging device wherein the signals reflect at least one of functional activation, chemical signatures, brain structure, neurotransmission, electromagnetic activity, perfusion effects and cell metabolism.
- 1 7. The method of Claim 6, wherein the neuroimaging device corresponds to one or more of a PET device, an fMRI device, an MEG device, an EEG device, a SPECT device, an IR device, a MRS device, and a functional CT device.

1 8. The method of Claim 4, further comprising:
2 aligning an imaging axis of an imaging device with the spinal cord of a subject
3 such that the imaging axis is aligned in a plane parallel to a spinal cord axis and
4 perpendicular to a cerebral mid-plane; and
5 obtaining images of CNS regions in the spine.

1 9. The method of Claim 1, wherein non-invasively obtaining signals of central
2 nervous system obtained non-invasively further comprises:
3 correcting the signals to reduce the effects of head motion;
4 transforming the signals into a uniform atomic space;
5 normalizing the transformed signals;
6 statistically mapping the normalized signal; and
7 locating the statistical maps over images reflecting at least one of: a uniform
8 atomic space, an average anatomic space, and an individual atomic space.

1 10. The method of Claim 1, wherein non-invasively obtaining signals of central
2 nervous system obtained non-invasively further comprises:
3 correcting the signals to reduce the effects of head motion;
4 aligning the signals with individual brain anatomy;
5 normalizing the transformed signals;
6 statistically mapping the normalized signal; and
7 locating the statistical maps over images reflecting at least one of: a uniform
8 atomic space, an average anatomic space, and an individual atomic space.

1 11. The method of Claim 1, wherein correlating the signals from reward/aversive
2 brain regions comprises evaluating the temporal nature of a neuroimaging signal
3 using waveform based correlation analysis (WCA).

1 12. The method of Claim 11, wherein data obtained from central nervous system
2 activity is segregated temporally.

1 13. The method of Claim 12 wherein data obtained from central nervous system
2 activity is segregated temporally into a plurality of phases.

1 14. The method of Claim 12, wherein the step of temporally segregating include
2 the step of segregating into an early phase waveform and a late phase waveform.

1 15. The method of Claim 13, wherein interpreting the results of the correlating
2 procedure further comprises correlating a plurality of pixels from regions in the CNS
3 to distinct waveforms.

1 16. The method of Claim 15, wherein the distinct waveforms correspond to at
2 least one of an early phase waveform and a late phase waveform.

1 17. The method of Claim 15, wherein interpreting the results of the correlating
2 procedure further comprises producing indices by quantifying the signals using at
3 least one of:

- 4 a spatial analysis;
- 5 a temporal analysis;
- 6 a comparison of slope analysis;
- 7 moment analysis;
- 8 laterality analysis;
- 9 synchrony analysis;
- 10 volume analysis;
- 11 power function used to generate indices;
- 12 power spectrum analysis used to generate indices;
- 13 integral analysis; and
- 14 derivative analysis.

1 18. The method of Claim 17, wherein interpreting the results of the correlating
2 procedure further comprises using one or more quantitative indices wherein at least
3 one of the one or more quantitative indices corresponds to one of:

- 4 a coordinate index from a uniform anatomic space;
- 5 a subregion index;
- 6 a subnuclear index;
- 7 a first time index T_p corresponding to a first moment of a signal response;
- 8 a second time index Δ corresponding to a second moment of a signal response;
- 9 a rate of signal change index;

10 an average time of response index;
11 a width of response index;
12 a tail index corresponding to a third moment of a signal response;
13 an R index;
14 an, L index;
15 a fractional laterally index
16 a correlation factor (r) index;
17 a volume index;
18 an exponent index;
19 an power spectrum index representing amplitudes of signal response
20 harmonics and subharmonics computed using a power spectrum analysis;
21 an index corresponding to one or more amplitudes changes computed using an
22 integral analysis of a signal response;
23 an index corresponding to a maximum rate of change of a signal response
24 computed using a derivative analysis of a signal response; and
25 an index corresponding to a time to achieve a maximum rate of change of a
26 signal response computed using a derivative analysis of the signal response.

- 1 19. The method of Claim 1, further comprising:
2 providing a known first set of indices;
3 measuring one or more signal responses in a subject;
4 generating a second set of indices by computing one or more index for each of
5 the one or more signal responses; and
6 comparing the second set of indices to the first set of indices.
- 1 20. The method of Claim 19 wherein:
2 the step of providing the known first set of indices, includes the step of
3 providing the known first set of indices to a processor; and
4 the step of comparing the second set of indices to the first set of indices
5 includes the steps of:
6 providing the second set of indices to the processor; and
7 comparing the second set of indices to the first set of indices using the
8 processor.

- 1 21. The method of Claim 20 wherein the processor corresponds to a neural
- 2 network processor.

- 1 22. The method of Claim 1, further comprising:
 - 2 selecting an experimental process which elicits a response in one or more
 - 3 reward/aversion regions of a subject;
 - 4 applying a reward/aversive stimulus to the subject to illicit the response; and
 - 5 correlating the experimental process to brain activity.

- 1 23. The method of Claim 22, wherein the experimental process further comprises:
 - 2 (a) administering to the subject at least one of: a drug, a gene product, a
 - 3 biopharmaceutical, a virus, a gene, one or more receptors, and a neurochemical;
 - 4 (b) applying a stimulus to the subject; and
 - 5 (c) measuring a brain response of the subject.

- 1 24. The method of Claim 23 further comprising measuring the response of the
- 2 same subject over time.

- 1 25. The method of Claim 24 wherein measuring the response of the same subject
- 2 over time comprises the steps of waiting a period of time and repeating steps (a) – (c).

- 1 26. The method of Claim 24 wherein measuring the response of the same subject
- 2 over time comprises the steps of waiting a period of time and performing the steps of:
 - 3 (a) administering a placebo to the subject;
 - 4 (b) applying a stimulus to the subject;
 - 5 (c) measuring an analgesic response of the subject.

- 1 27. The method of Claim 22, wherein the experimental process comprises:
 - 2 exposing a subject to at least one of a thermal, mechanical or chemical
 - 3 stimulus; and
 - 4 measuring the response of the subject to the stimulus.

- 1 28. The method of Claim 1, further comprising:
2 administering a treatment to the subject; and
3 correlating the treatment to brain activity.
- 1 29. The method of Claim 26, wherein the treatment corresponds to at least one of
2 a drug/gene product, a surgical treatment, a radiation treatment, a behavioral
3 treatment, and an acupuncture treatment.
- 1 . The method of Claim 1 wherein the step of interpreting the correlation result
2 comprises:
3 correlating the signals from pain and reward brain regions; and
4 comparing results of the correlation to a predetermined index.
- 1 31. A method for determining the efficacy of a treatment corresponding to one of
2 a compound, a drug, a gene product, a virus, a gene, a receptor, a neurochemical, a
3 biopharmaceutical, the method comprising:
4 non-invasively obtaining base line signals of central nervous system (CNS)
5 activity;
6 administering a dose of the treatment;
7 localizing signals to specific anatomical and functional CNS regions
8 corresponding to a reward/aversion region; and
9 correlating the signals in the reward/aversion brain region; and
10 interpreting the results of the correlation.
- 1 32. The method of Claim 31, wherein the dose is a therapeutic dose.
- 1 33. The method of Claim 31, wherein the dose is a sub-therapeutic dose.
- 1 34. The method of Claim 31, further comprising producing an objective
2 determination that the administered treatment alters the experience of pain in response
3 to aversive stimuli or non-aversive stimuli.
- 1 35. A method of evaluating a stimulus comprising:
2 (a) measuring a plurality of indices;

- 3 (b) forming a matrix pattern with the indices;
- 4 (c) measuring a subject response to a stimulus;
- 5 (d) using the subject response to compute indices for the subject; and
- 6 (e) comparing the subject indices to the matrix pattern indices to objectively
- 7 determine the condition of the subject.

1 36. The method of Claim 35 wherein the step of measuring a response includes
2 the step of administering a mechanical, thermal or chemical stimulus to the subject.

1 37. The method of Claim 36 wherein the stimulus corresponds to one of a drug
2 and a treatment.

1 38. A system for measuring indices of brain activity comprising:
2 a central nervous system (CNS) imaging device;
3 a localization processor to map signals to specific anatomical and functional
4 brain regions;
5 a correlation processor to correlate the signals from pain and reward brain
6 regions;
7 a neural network processor.